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Modelling the effect of support practices (P-factor) on the reduction of soil erosion by water at European scale

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ABSTRACT

The USLE/RUSLE support practice factor (P-factor) is rarely taken into account in soil erosion risk modelling at sub-continental scale, as it is difficult to estimate for large areas. This study attempts to model the P-factor in the European Union. For this, it considers the latest policy developments in the Common Agricultural Policy, and applies the rules set by Member States for contour farming over a certain slope. The impact of stone walls and grass margins is also modelled using the more than 226,000 observations from the Land use/cover area frame statistical survey (LUCAS) carried out in 2012 in the European Union.

The mean P-factor considering contour farming, stone walls and grass margins in the European Union is estimated at 0.9702. The support practices accounted for in the P-factor reduce the risk of soil erosion by 3%, with grass margins having the largest impact (57% of the total erosion risk reduction) followed by stone walls (38%). Contour farming contributes very little to the P-factor given its limited application; it is only used as a support practice in eight countries and only on very steep slopes. Support practices have the highest impact in Malta, Portugal, Spain, Italy, Greece, Belgium, The Netherlands and United Kingdom where they reduce soil erosion risk by at least 5%. The P-factor modelling tool can potentially be used by policy makers to run soil-erosion risk scenarios for a wider application of contour farming in areas with slope gradients less than 10%, maintaining stone walls and increasing the number of grass margins under the forthcoming reform of the Common Agricultural Policy.

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1. Introduction

The Common Agricultural Policy (CAP) is the main EU policy through which farmers are receiving incentives in the

European Union (EU). In order to get those incentives, farmers must comply with “best practice” landuse management practices (named cross-compliance). The main component of cross-compliance is the farmer’s obligation to keep his land under Good Agricultural and Environmental Condition (GAEC,

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2009). This regulation requests the farmers to prevent soil erosion, conserve soil organic carbon and maintain soil structure. An option to assess the effect of GAEC on soil erosion reduction is based on the use of soil erosion risk models. At national scale, models based on the Universal Soil Loss Equation (USLE) are most commonly applied (Panagos et al., 2014a).

Of the six RUSLE/USLE input factors (Renard et al., 1997), values for the support practice P-factor are considered as the most uncertain (Haan et al., 1994; Morgan and Nearing, 2011). The P-factor accounts for control practices that reduce the erosion potential of runoff by their influence on drainage patterns, runoff concentration, runoff velocity and hydraulic forces exerted by the runoff on the soil surface (Renard et al., 1991). It is an expression of the overall effects of supporting conservation practices – such as contour farming, strip cropping, terracing, and subsurface drainage – on soil loss at a particular site, as those practices principally affect water erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the volume and rate of runoff (Renard et al., 1997). The value of P-factor decreases by adopting these supporting conservation practices as they reduce runoff volume and velocity and encourage the deposition of sediment on the hill slope surface. The lower the P-factor value, the better the practice is for controlling soil erosion. Human influence on soil erosion control is important to include in soil erosion risk assessment, but there is no global reference because erosion control is a very local activity (Yang et al., 2003).

P-values can be derived either from image classifications using remote sensing data or from previous studies or even from expert knowledge. Karydas et al. (2009) have mapped landscape objects (terraces, roads, physical obstacles) with object-oriented image analysis (OAA) and assigned P-values by expert knowledge in the Kolymbari catchment study in Crete. Another approach is to use IMAGE 2006 and Sobel filters for identifying physical obstacles (Panagos et al., 2014b) that can reduce runoff and soil erosion. The image classifications approach requests very high resolution remote sensing datasets and some experimental results which are currently not available.

The literature reports various tables and formulas proposing P-factor values for the different supporting conservation practices adopted to different environmental contexts (e.g. Wischmeier and Smith, 1978; Renard et al., 1997; Foster et al., 2002). Typical values range from about 0.2 for reverse-slope bench terraces, to 1.0 where there are no erosion control practices (Wischmeier and Smith, 1978). The effectiveness of the support conservation measures is obtained from plot studies and often applied at small catchments. However, since it is difficult to quantify the impact of different support practices applied in very large areas (e.g. Europe), only a first estimate of the P-factor can be calculated at European scale.

An alternative approach for an approximation of the P-factor is based on empirical equations. For instance, the Wener's method assumes that the P-factor is linked to topographical features. This method is commonly employed to determine P-factor values using as input the slope gradient (%) (Lufafa et al., 2003; Fu et al., 2005; Terranova et al., 2009).

Our study does not use such equations as slope gradient is already incorporated in the topographic LS factor.

The main objective of this study is to estimate the support practice factor (P-factor) based on earth observation datasets at European scale (EU-28) following the literature guidelines and taking into account the current agro-environmental policies that are implemented in the individual member states. The proposed P-factor model for Europe takes into consideration contour farming, stone walls and grass margins. Management practices such as reduced tillage, cover crops and plant residues are incorporated in the land cover and management practice factor (C-factor of the RUSLE). More specifically, this study aims to:

- 1) Estimate the P-factor values for arable lands in Europe based on the Common Agricultural Policy implementation.
- 2) Assess the impact of conservation practices such as stone walls and grass margins in reducing soil loss at European scale.
- 3) Discuss the implications of policy scenarios that may affect those support practices.

2. Policy context and materials

2.1. Good Agricultural and Environmental Condition (GAEC) measures applied in the EU Member States

Member States have the flexibility to define the contents of GAEC requirements taking into account the local conditions (Angileri et al., 2011). Regarding protection of soils against soil erosion, GAEC has introduced among others the prevention of erosive farming practices (ploughing and planting up and down the slope) in hilly areas and the maintenance of landscape features such as stone walls (and terraces) and buffer strips. Some Member States have set the requirement for contour ploughing (and ban up- and downslope cultivation) for areas exceeding a certain slope gradient (Table 1).

The maintenance of dry stone walls is among the GAEC standards that Member States have adopted. Stone walls are considered effective for reducing slope length and as a consequence soil erosion (Bazzoffi, 2009). Moreover, according to GAEC standards, small landscape elements such as hedges or buffer strips should not be removed as they protect habitats and reduce runoff volumes.

2.2. Land use/cover area frame statistical survey (LUCAS)

The study uses the Land use/cover area frame statistical survey named LUCAS (LUCAS, 2012) which includes ground observations both on land use/cover and landscape features for over 270,000 observation points visited by surveyors in 2012. The survey has been made in the 27 member states (EU-27) of the European Union covering an area of ca. 4.3 million km² with an average density of 1 observed point every 16 km². Surveyors recorded data on land use/cover plus additional information such as slope gradient, presence of grazing, height of trees and irrigation management. The surveyor also collects multi-directional photographs and walks eastwards

Table 1 – GAEC application (mainly on contour farming) in Member States.

Member state	Farming practice	Slope (%)	Crop (if specified)
Belgium-Flanders (BE-F)	Crop to be sown along contours (if plot extends >100 m in that direction)	Any	Winter cereals, spring grain or linen
Cyprus (CY)	Cultivation along the contour	>10	
Estonia (EE)	Cultivation along the contour	>10	
Denmark (DK)	Reduced till	>21	
Greece (GR)	Cultivation along or diagonal to the contour (cross slope contour farming)	>10	
Italy (IT)	Contouring every 80 m of agricultural land (named solco in Italian)		
Malta (MT)	Cultivation along the contour	>10	
Romania (RO)	Soil tillage along the contour	>12	Row crops
Slovenia (SI)	Ploughing along contour	>20	
Spain (ES)	No overturn of soil in the direction of the maximum slope	>10	Herbaceous crops
	No overturn of soil in the direction of the maximum slope	>15	Vineyards, olive groves and nut crops

**Fig. 1 – Examples of dry stone walls (photos above) and grass margins (photos below) reported in LUCAS survey.**

along a transect of 250 m recording the sequence of land-cover types and linear landscape features. Among the total number of observations, 226,653 records (83.9%) are considered valid for this study because the rest were not completed by a surveyor (Van Der Zanden et al., 2013). Invalid points were well distributed all over Europe. The data is geo-referenced and is available in the LUCAS database (LUCAS, 2012). Among the landscape features recorded by a surveyor (LUCAS, 2013), we focused in this study on stone walls and grass margins (Fig. 1).

2.2.1. Stone walls

Dry stone walls are widespread landscape features in the Mediterranean and especially in the islands (Malta, Sicily, Cyprus, Isle Balearides, Aegean Islands). These stone walls were primarily used to delimit parcels being bequeathed by farmers to their children and to clean the land from stones.

This also includes stone heaps which were collected by the farmer on the field (Fig. 1a) even though not in a linear form. Stone walls prevent soil erosion; especially in hilly areas. Their predominance in Southern Europe is also linked to the availability of stones in soil (Poesen et al., 1994; Panagos et al., 2014c).

Stone walls should be at least 20 m long in order to be recorded by a LUCAS surveyor. According to the LUCAS observations, stone walls have been recorded in 11,141 (4.9%) transects. The largest number of stone walls has been observed in Spain, France, Italy and Portugal (Table 2). In all Mediterranean countries (IT, ES, PT, GR, CY, MT) as well as in Ireland and United Kingdom the density of stone walls (number of stone walls divided by total number of observations) exceeds 8% (Table 2). The highest density is noticed in Malta (72.5%) followed by Portugal (22.6%), Ireland and Spain.

Table 2 – Presence of stone walls and grass margins in EU Member States according to the LUCAS survey in 2012.

Country		Stone walls			Grass margins			Total No of valid observations
Name	Code	No of observations	% of grand total	Density (%)	No of observations	% of grand total	Density (%)	
Austria	AT	45	0.4%	0.8%	1593	2.6%	28.9%	5504
Belgium	BE	20	0.2%	0.9%	1014	1.7%	45.6%	2224
Bulgaria	BG	18	0.2%	0.3%	1319	2.2%	22.6%	5838
Cyprus	CY	104	0.9%	8.4%	164	0.3%	13.3%	1235
Czech Rep.	CZ	27	0.2%	0.5%	784	1.3%	14.5%	5400
Germany	DE	54	0.5%	0.2%	7416	12.1%	32.3%	22,947
Denmark	DK	10	0.1%	0.3%	995	1.6%	33.0%	3016
Estonia	EE	3	0.0%	0.2%	273	0.4%	15.5%	1765
Spain	ES	4165	37.4%	13.8%	9020	14.7%	29.8%	30,287
Finland	FI	78	0.7%	0.7%	2080	3.4%	19.6%	10,595
France	FR	1444	13.0%	4.5%	12,161	19.9%	37.8%	32,182
Greece	GR	565	5.1%	8.9%	1379	2.3%	21.7%	6361
Hungary	HU				1084	1.8%	25.4%	4273
Ireland	IE	346	3.1%	13.9%	419	0.7%	16.8%	2493
Italy	IT	1295	11.6%	8.1%	5256	8.6%	33.0%	15,922
Lithuania	LT	2	0.0%	0.1%	619	1.0%	17.2%	3600
Luxembourg	LU	6	0.1%	2.9%	77	0.1%	36.8%	209
Latvia	LV	3	0.0%	0.1%	403	0.7%	12.4%	3253
Malta	MT	50	0.4%	72.5%	20	0.0%	29.0%	69
Netherlands	NL	2	0.0%	0.1%	714	1.2%	38.8%	1841
Poland	PL	14	0.1%	0.1%	5599	9.1%	29.0%	19,292
Portugal	PT	1377	12.4%	22.6%	1131	1.8%	18.6%	6091
Romania	RO	7	0.1%	0.1%	1948	3.2%	19.3%	10,119
Sweden	SE	542	4.9%	2.8%	1891	3.1%	9.8%	19,341
Slovenia	SI	78	0.7%	5.5%	300	0.5%	21.0%	1430
Slovakia	SK	4	0.0%	0.2%	295	0.5%	14.5%	2039
United Kingdom	UK	882	7.9%	9.5%	3270	5.3%	35.1%	9327
Grand total		11,141	100.0%	4.9%	61,224	100.0%	27.0%	226,653

The LUCAS earth observations for stone walls were compared with the data from the Farm Structure Survey (FSS) which was also performed by Eurostat in 2010 (FSS, 2010). According to FSS, 727,830 out of 12,248,040 agricultural holdings (5.9%) have reported stone walls in EU-28. The FSS data could not be used in this study as they are not geo-referenced. The FSS data set report the same trends for stone walls in Mediterranean countries (PT, ES, CY, MT, GR, IT) as the LUCAS survey.

2.2.2. Grass margins

In the LUCAS survey, grass margins are defined as strips of mainly uncultivated land with vegetation dominated by grasses or herbs. Grass margins are recorded in the LUCAS database when their width is between 1 and 3 m and the length exceeds 20 m (LUCAS, 2013). Grass margins are mainly

located at the edge of the fields, between cropped areas (beetle banks) (Fig. 1b) or bordering roads and tracks (roadside verge). The grass margins can be spontaneous or planted and they are managed by farmers.

According to the LUCAS observations, grass margins have been reported for 61,224 (27%) transects (Table 2). Large countries (FR, DE, ES, IT, PL) had the higher absolute numbers of grass margins. The highest density of grass margins compared to the total number of observations is found in Belgium (45.5%), Netherlands (38.8%), France (37.8%), Luxembourg (36.8%) and the United Kingdom (35.1%).

For both, stone walls and grass margins, the surveyors have also recorded their density inside the 250 m transect. The vast majority of the observed transects where those features are present, has 1 feature per transect (Table 4).

2.3. CORINE Land Cover

The CORINE Land Cover datasets (CLC, 2014) contain homogeneous data on land cover areas provided as polygons. The datasets are outputs of harmonised procedures based on a common classification system, and can therefore be easily compared. Land cover is classified in 44 classes, which are grouped into three hierarchical levels. The used CLC data are in raster format at pixel size of 100 m and refer to the year 2006. The CLC data are used for stratification of support practices.

Table 3 – P-factor for contour support practice for different slope gradient.

Slope (%)	Support practice factor for contouring, P_c
9–12	0.6
13–16	0.7
17–20	0.8
21–25	0.9
>25	0.95

Table 4 – Density of stone walls and grass margins along a transect (LUCAS database) and assigned P-factor (P_{sw} is stone walls sub-factor, P_{gm} is grass margins sub-factor) values for Europe.

No of features (stone walls or grass margins)	% of total stone walls observations	P_{sw}	% of total grass margins observations	P_{gm}
0	95.08%	1	72.99%	1
1	2.51%	0.707	11.36%	0.853
2	1.10%	0.577	9.73%	0.789
3	0.53%	0.500	3.06%	0.750
4	0.32%	0.448	1.70%	0.724
5	0.15%	0.408	0.60%	0.704
6	0.10%	0.378	0.30%	0.689
7	0.06%	0.354	0.12%	0.677
8	0.05%	0.334	0.07%	0.667
>8	0.09%	0.317	0.07%	0.660
Total	100.0%		100.0%	

3. Methods

At European level, the effect of support practices (compulsory for farmers to receive incentives under the CAP-GAEC) on soil loss were assessed by P-factor estimation taking into account: (a) contour farming, (b) maintenance of stone walls, and (c) grass margins. P-factor was proposed as a product of those 3 sub-factors by Blanco and Lal (2008); applied by Lopez-Vicente and Navas (2009):

$$P = P_c \times P_{sw} \times P_{gm} \quad (1)$$

where P_c is the contouring sub-factor for a given slope of a field, and P_{sw} is the stone walls sedimentation sub-factor (known as terrace sub-factor) and P_{gm} is grass margins sub-factor (known as strip cropping sub-factor and buffer strips). In the same context, Angima et al. (2003) computed the P-factor as a product of individual support practices (contour farming, terracing and strips) that are used in combination to reduce soil erosion in Kenya.

3.1. Contour farming sub-factor

Contouring is a specific support practice applied only in croplands (CORINE land cover classes 21x) which account for around 25.2% of the total European Union land area. Contour farming means that farmers apply certain field practices (ploughing, planting) along contours, perpendicular to the normal flow direction of runoff. Contour cultivation reduces runoff velocity by increasing up- and downslope surface roughness. The increased surface roughness reduces water velocity providing more time for infiltration (Stevens et al., 2009). The effectiveness of contour farming in reducing soil erosion depends on the slope gradient (Table 3).

In the Good Agricultural and Environmental Conditions (GAEC), each country has the flexibility to decide the compulsory requirements for farmers to apply contour farming. Among the EU Member States, only 10 have applied contour farming. It was not possible to estimate the contour farming sub-factor in Belgium (Flanders) and Denmark as it was not specified in their GAEC. Using the Digital elevation model at 25 m resolution, the arable lands of 8 countries (Table 1) have been attributed a P-factor based on their topographic feature (slope %) and the P-factors proposed by Morgan (2005) in Table 3:

3.2. Stone walls sub-factor

Stone walls are mainly built on hilly land and reduce the velocity of overland flow and as a consequence reduce soil erosion rates (Morgan, 1995). Slope length is reduced due to the presence of stone walls. In the longer term, the hillslope gradient may even be reduced due to progressive terrace formation (Nyssen et al., 2007). Finally, stone walls trap sediments within the borders of the field parcels. Stone walls, even if they are partly degraded, continue to provide protection against soil erosion (Bazzoffi and Gardin, 2011).

For 14 plots (representing 21 plot-year data) in Europe and the Mediterranean, Maetens et al. (2012) calculated that stone wall terraces reduced soil loss to 0.75 (mean) and 0.35 (median) of the soil loss values for control plots (i.e. without terraces). Regarding the efficiency of stone walls, field experiments at a plot scale in Ethiopia showed that dry stone walls led to a 68% reduction of soil erosion (Gebremichael et al., 2005). In the Tigray highlands of Ethiopia, Munro et al. (2008) proposed P-factor values depending on the quality of stone walls (remains: 0.8, poor: 0.6, moderate: 0.4, good: 0.2). These values can also be interpolated and applied in non-arable lands. In Kenya, Angima et al. (2003) has calculated the P-factor value between 0.5 and 0.7 depending on the gradient and the density of stone walls. Mediterranean traditional dry stone walls (in Greece) do not protect the soil surface from water erosion completely, because of the existing slope gradient between successive terraces (Koulouri and Giourga, 2007). In Mediterranean countries stone walls are also built around olive trees (Prevati et al., 2010).

A simple model estimates soil loss with or without the presence of stone walls in various land use, rainfall erosivity, soil erodibility and topographic conditions (scenarios). This model assumes that stone walls reduce slope length; thus, the impact of stone walls on soil loss reduction can be predicted. We estimated the impact of stone walls in reducing soil loss for 4 different scenarios:

- Forest with high R-factor = $1500 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$, low K-factor = $0.02 \text{ ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1}$ and slopes up to 45%.
- Arable land with medium R-factor = $750 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$, mean K-factor $0.03 \text{ ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1}$ and slopes up to 3%.

Table 5 – Presence of stone walls and grass margins per CORINE Land Cover class in Europe.

Land Cover	CORINE classes	% of stones walls	% of grass margins
Arable lands	211–213	12.5%	48.9%
Permanent crops	221–223	9.2%	4.3%
Pastures	231	11.4%	9.9%
Heterogeneous agr. areas	241–244	29.0%	16.7%
Forests	311–313	15.0%	12.5%
Scrub/herbaceous vegetation	321–324	18.4%	3.5%
Open Spaces/little vegetation	331–334	0.9%	0.1%
Artificial land – water bodies – other	1×, 4×, 5×	3.8%	4.1%
Total		100.0%	100.0%

- c) Grassland with R-factor = $1000 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$, low K-factor = $0.02 \text{ ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1}$ and slopes up to 10%.
- d) Pastures with R-factor = $900 \text{ MJ mm ha}^{-1} \text{ h}^{-1} \text{ yr}^{-1}$, low K-factor = $0.02 \text{ ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1}$ and slopes up to 5%.

We ran 4 land use scenarios with different stone wall densities and also considered the overall impact of stone walls on soil losses measured at experimental sites (Gebremichael et al., 2005; Angima et al., 2003; Munro et al., 2008; Koulouri & Giourga, 2007; Maetens et al., 2012) in assigning P_{sw} values (Table 4). P_{sw} -factor values range between 0.32 and 0.71 depending on stone walls density.

The above-mentioned experimental studies showed the effectiveness of stone walls in all land use types. The analysis of stone walls per CORINE land cover class shows a relatively high number of those features in heterogeneous agricultural areas and scrub lands (Table 5). Thus, the impact of stone walls is taken into account for all CORINE land cover classes except for artificial land and water bodies.

3.3. Grass margins sub-factor

Haan et al. (1994) considered grass margins as one of the most effective measure for reducing sediment delivery. The grass margins obstruct runoff, induce infiltration, trap sediments and reduce sediment transport. The reduction of sediment yield when applying grass margins is relatively small (Verstraeten et al., 2002). Experimental results show that grass margins can trap between 10% and 30% of inflowing sediment (Dillaha et al., 1987; Haan et al., 1994). In USA, Dabney et al. (1999) estimated the P-factor to be 0.81 for hedge rows (1–2 m wide) of dense vegetation. Using GUSED (Griffith University Soil Erosion and Deposition) model, Hussein et al. (2007) estimated a reduction of soil loss between 5.9% and 11.6% (P-factor = 0.88–0.94) due to buffer strips in different slope conditions. In two different catchments (Gibuuri, Kianjuki) in Kenya where buffer strips have been applied, two studies (Angima et al., 2003; Hessel and Tenge, 2008) found P_{gm} sub-factor equal to 0.7. Nyssen (2001) estimated that grass strips can accumulate half of the sediment yield compared to stone walls.

Taking into account the values of P-factor for grass margins reported in the literature (Dillaha et al., 1987; Haan et al., 1994; Dabney et al., 1999; Angima et al., 2003; Hessel and Tenge, 2008), we assumed that grass margins trap on average half of the sediments compared to those trapped by stone walls. Thus, depending on the density of grass margins, the P_{gm} -factor will vary from 0.66 to 0.85 (Table 4).

Almost half of the observed grass margins are located in arable lands (Table 5). The impact of grass margins is estimated only for agricultural areas (arable – permanent), pastures and heterogeneous agricultural areas which in total account for 80% of the observation points having grass margins.

3.4. Spatial interpolation of stone walls and grass margins

The LUCAS ground observations have been performed at 270,000 points. The transect findings record the density of stone walls and grass margins. To assess the impact of those features to the whole European Union area, a spatial interpolation should be performed. In the environmental domain, spatial interpolations approaches range from simple interpolation such as Inverse Weighted Distance (IWD) to Ordinary Kriging (OK) and even more complex regression models.

Since the objective of this study is to capture the density of stone walls and grass margins (spatial patterns) and by using the past experience in this field (Van Der Zanden et al., 2013), the ordinary Kriging method was selected for spatial interpolation. This technique assumes a spatial homogeneous surface with constant variance and constant mean. In this study, the ordinary Kriging was based on 25 observation points for the radius setting. More complex regression models are recommended for a spatial interpolation at regional scale.

4. Results and discussion

4.1. P-factor assessment at European level

The contour sub-factor (P_c) was estimated based on a Digital Elevation Model (DEM) at 25 m resolution. The mean P_c for the EU-28 was calculated to 0.9985 (0.9942 in arable lands) due to the limited number of countries applying contour farming in GAEC and due to the application of this support practice mostly to slopes over 10%. The largest effect of contour farming is estimated for Cyprus (0.990) followed by Spain and Greece and the lowest mean value is found in Slovenia due to the very limited application of contouring (only on slopes > 20%).

The stone walls sub-factor (P_{sw}) was estimated based on the interpolated stone walls dataset at 1 km resolution. The mean P_{sw} for the EU-28 was calculated to be 0.9884 and the largest effect of stone walls is noticed in Malta ($P_{sw} = 0.529$) followed

Table 6 – Support practice (P-factor) and sub-factors per country.

Country	P_c (contouring)	P_{sw} (stone walls)	P_{gm} (grass margins)	P-factor
AT	1	0.9996	0.9887	0.9883
BE	1	0.9998	0.9467	0.9465
BG	1	0.9999	0.9912	0.9911
CY	0.9909	0.9828	0.9991	0.9730
CZ	1	0.9999	0.9983	0.9982
DE	1	0.9998	0.9784	0.9782
DK	1	0.9999	0.9844	0.9843
EE	0.9995	0.9998	0.9996	0.9989
ES	0.9926	0.9580	0.9778	0.9293
FI	1	0.9998	0.9943	0.9942
FR	1	0.9935	0.9691	0.9627
GR	0.9939	0.9676	0.9883	0.9502
HR	1	0.9999	0.9995	0.9994
HU	1	1	0.9840	0.9840
IE	1	0.9738	0.9952	0.9690
IT	0.9992	0.9786	0.9725	0.9519
LT	1	0.9999	0.9980	0.9980
LU	1	0.9991	0.9725	0.9716
LV	1	0.9999	0.9995	0.9995
MT	0.9993	0.5299	0.9915	0.5251
NL	1	0.9999	0.9561	0.9561
PL	1	0.9999	0.9781	0.9781
PT	1	0.9245	0.9921	0.9178
RO	0.9948	0.9999	0.9950	0.9898
SE	1	0.9976	0.9984	0.9961
SI	0.9999	0.9919	0.9940	0.9860
SK	1	0.9999	0.9986	0.9985
UK	1	0.9878	0.9647	0.9528

by Portugal and the rest of the Mediterranean countries (Table 6). The interpolated stone wall dataset has less uncertainty compared to the grass margins dataset. The Root Mean Square Error (RMSE) for the stone wall interpolation was 0.568 and 1.031 for the grass margins which was in line with previous modelling efforts (Van Der Zanden et al., 2013).

The grass margins sub-factor (P_{gm}) was estimated based on the interpolated grass margins dataset at 1 km resolution. The mean P_{gm} for the EU-28 was calculated to be 0.9829 with the highest effect in reducing soil loss in Belgium, Netherlands, United Kingdom and France (Table 6). This sub-factor is the most important (compared to contouring and stone walls) in support practices estimation for Europe due to the abundance of grass margins (observed in 27% of the LUCAS transects).

The mean P-factor in the EU-28, combining the 3 sub-factors, is estimated to be 0.9702 (Fig. 2). Due to the high density and impact of stone walls, Malta has the lowest P-factor (0.525) followed by Portugal, Spain and Belgium which have P-factor values less than 0.95. The implementation of support practices is very limited in the Baltic States, Slovakia and Czech Republic with P-factor values close to 1.0. The support practices have greater influence in agricultural land use as they reduce soil erosion risk by 5% ($P_{agriculture} = 0.95$).

The P-factor map at 1 km resolution (Fig. 2) spots the areas where support conservation practices are mostly applied. The importance of stone walls in reducing soil loss especially in sloping areas (e.g. Cinque Terre in Italy, Lesvos in Greece, Malta, Priorat/Catalonia in Spain, Douro in Portugal) (Stanchi et al., 2012) is highlighted in the P-factor map (Fig. 2). Support practices are extremely important in reducing soil loss

in sloping and high erosive areas. Regarding land uses, permanent crops with a relatively small coverage of 2.4% in EU lands have a share of 9.2% in stone walls (Table 5). So, it is crucial to invest in stone walls in olives fields of Crete and vineyards in Spain (hilly and erosive areas) than in flat areas such as Po plain in Italy.

The P-factor map can further be combined with the rainfall erosivity (R-factor) in Europe (Panagos et al., 2015a). The most erosive areas (75th percentile; R-factor > 900 MJ mm ha⁻¹ h⁻¹ yr⁻¹) mainly located in the Mediterranean basin have mean P-factor equal to 0.9574. Contrary, in the less erosive areas (25th percentile; R-factor < 410 MJ mm ha⁻¹ h⁻¹ yr⁻¹) the mean P-factor is 0.9845. The support practices are mainly focusing in erosive prone areas.

At European scale and for policy makers, it is recommended to aggregate the data at regional level. NUTS2 (Nomenclature of territorial units for statistics) level represents regions of 0.8–3 million people at which regional policies are implemented and agricultural data are available. The aggregated P-factor map (Fig. 3) at NUTS2 level classifies the regions according to the application of support practices. The highest concentration of support practices driven mainly by the density of stone walls is found in 3 island regions: Malta, Isle Balearides (ES) and Notio Aigaio (GR). Those are followed by Puglia (IT), Comunidad Valenciana (ES), Norte (PT) and Voreio Aigaio (GR) which all have P-factor values less than 0.85 (Fig. 3). P-factor values in the range of 0.85–0.90 are found in regions from Mediterranean countries, United Kingdom, The Netherlands and Belgium.

The stone walls are usually found in hilly areas while the grass margins are observed in more gently sloping areas. The

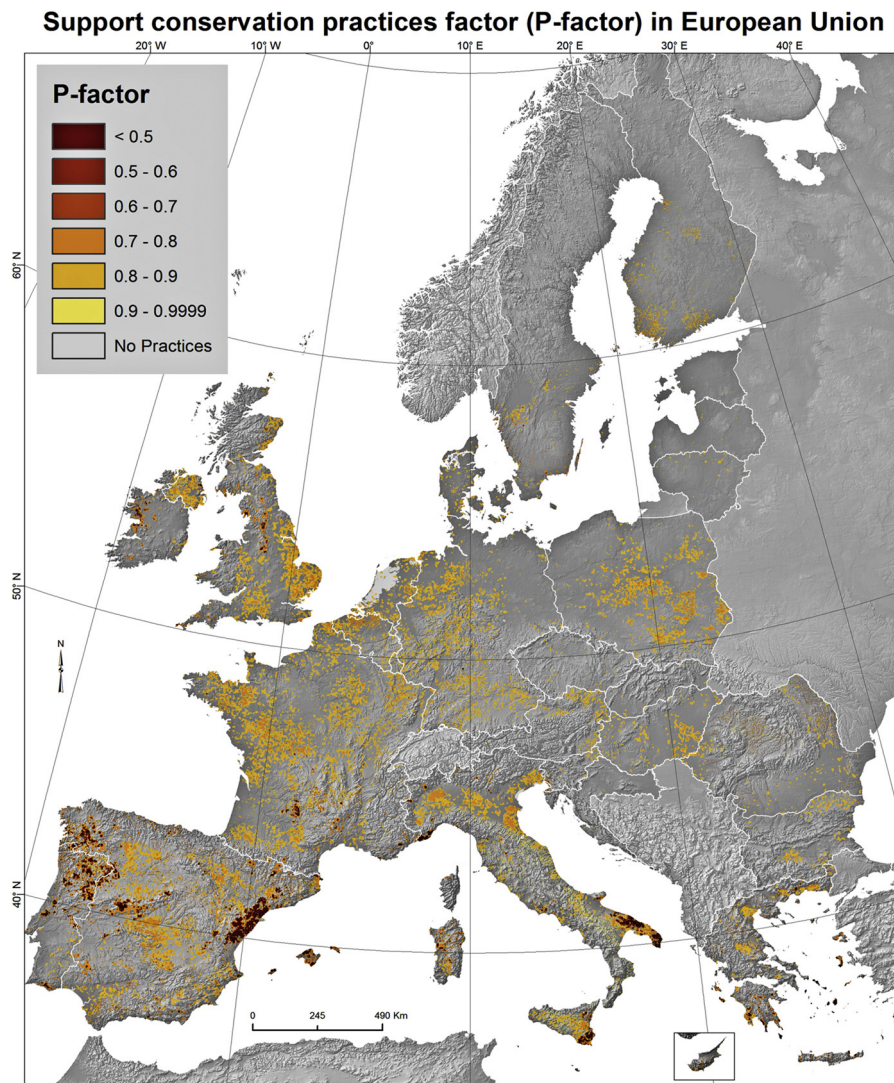


Fig. 2 – Support practice factor (P-factor) in the European Union.

protective role of stone walls is higher compared to the grass margins as they can reduce soil erosion in erosion-prone hilly areas. Other protective practices such as subsurface drainage or fences were not taken into account due to either a limited number of observations at European scale or the lack of data on their effectiveness in reducing soil loss. The proposed methodology is repeatable as LUCAS survey is performed in Europe every 3 years. This creates an opportunity for future monitoring of changes in the P sub-factors for stone walls and grass margins.

4.2. Limitations of the results

The contour sub-factor estimation is based on the assumption that farmers are following the GAEC guidelines which is true as they receive incentives and they are controlled by authorities. However, contour farming may also be applied in areas which have not been recorded in this study due to lack of observations.

The presence of stone walls and grass margins in this model depends on the surveyed points selected in LUCAS. Due

to financial constraints, the number of visited points is limited. The original findings in LUCAS earth observations are also influenced by the transect length. The interpolated datasets (stone walls, grass margins) are also dependent on the selected interpolation technique.

The impact of grass margins is based on certain assumptions as those features have different physical forms (height, density and seasonal effect) from country to country. Moreover, the influence of the practices (stone walls, grass margins) depends much on the slope direction and slope gradient. To overcome these limitations, a conservative model approach has been followed as the impact of grass margins and stone walls has been estimated to a minimum level.

4.3. Policy making and options for maintenance of support practices

The proposed P-factor estimation methodology is a useful tool for policy makers to simulate policy relevant scenarios. For instance, the scenario of applying contour farming in all European arable lands (EU-28) having slopes steeper than 10%

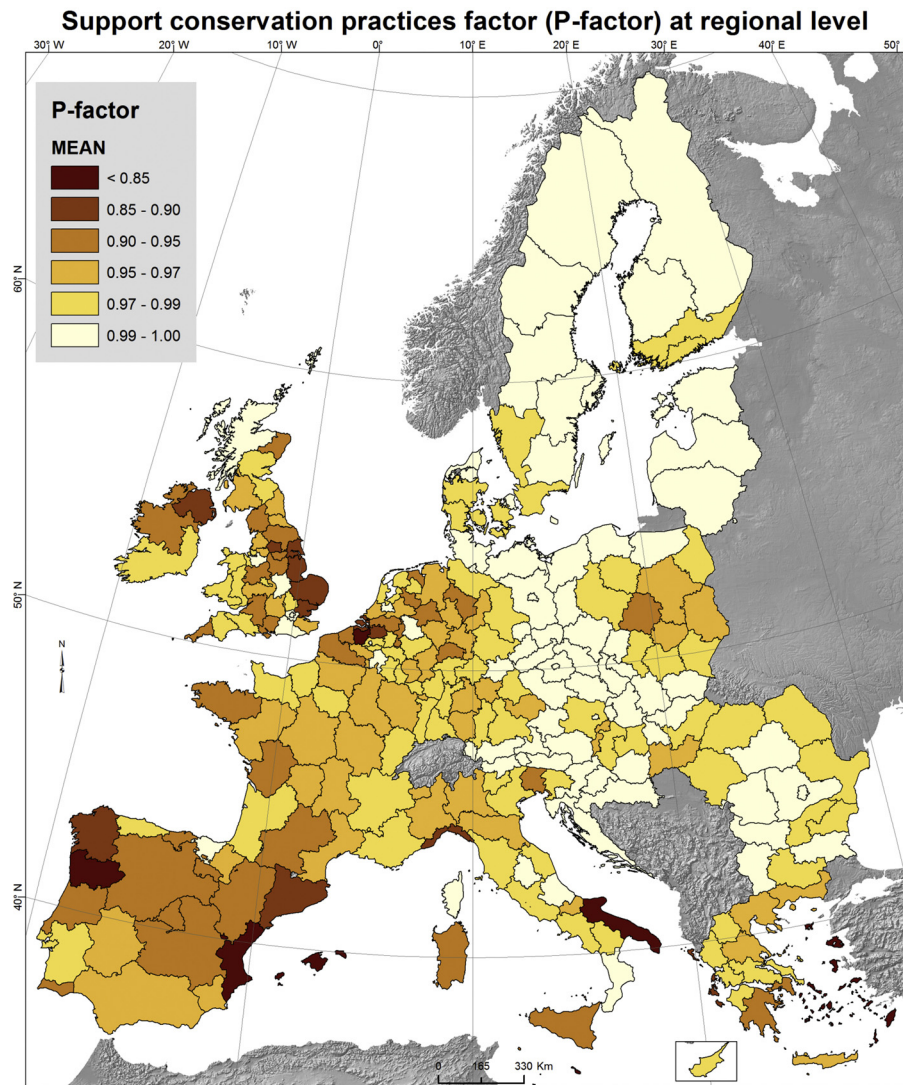


Fig. 3 – Mean P-factor at regional (NUTS2) level in the European Union.

will result in a reduction of the contour sub-factor (P_c) to 0.9942 (0.978 in arable lands). As a consequence the mean P-factor in Europe will be reduced by 0.5% (0.966). The countries where the largest erosion-reducing impact of this measure would be achieved are Italy ($P_c = 0.9843$), Czech Republic ($P_c = 0.9872$) and Bulgaria ($P_c = 0.9893$).

A drastic scenario of applying contour farming in all European arable lands having slopes steeper than 5% will result in a $P_c = 0.977$ and P-factor = 0.949. The preservation of stone walls is very important for soil conservation on steep slopes whereas the increase of grass margins may potentially reduce soil erosion risk in cropland on rolling topography. A scenario of combining contour farming in slopes steeper than 5% with doubling grass margins and preserving stone walls may result in P-factor = 0.92.

In the new EU Common Agricultural Policy (CAP 2014–2020), the regulations state that farmers must ensure that 5% of their land is set aside from farming as an Ecological Focus Area (EFA) to receive their full payment under the Basic Payment Scheme. Buffer strips are listed as one of the options but they must be on or adjacent to arable land, next to a

watercourse or parallel to it (CAP Rural Development Plan 2014–2020).

Also, research has to identify the areas and conditions where the support practices are more efficient. For example, perennial grass which is more rigid than grass margins can reduce soil loss by 50% (Dabney et al., 2009). Perennial grass is planted close to the contour and differs from other types of grass margins in that it resists being inundated by runoff flows and remains erect at all times during the year, including dormant periods. In the future, GAEC can also set maximum livestock rates per region, land use and slope to prevent compaction and overgrazing which leads to erosion.

European policy makers have become aware of the costs of soil erosion during the recent decade (Boardman and Poesen, 2006); thus they focus on strengthening both the soil and crop management practices (reduced tillage, plant residues and cover crops) and the support practices (contouring, maintenance of stone walls and grass margins) for reducing soil erosion risk. The present P-factor modelling approach together with the estimation of the C-factor at European scale (Panagos et al., 2015b) is evaluation tools for estimating the

potential of interventions for soil conservation. Experimental results demonstrated that combined practices (e.g. cover crops and contour farming) have better results in controlling sediment loss (Verstraeten et al., 2002). A cost/benefit analysis of the support practice measurements is also needed. This will allow drawing conclusions if the effectiveness of the conservation measures is financially sustainable to support additional subsidies to farmers in order to apply those support practices. Those conservation measures should focus to erosion prone areas such as arable lands on hilly slopes suffering from high erosivity. A significant contribution of this study is the quantification of the observed conservation measures. It is extremely essential to improve the model input data quality with the farmers' participation and the more accurate LUCAS survey observations.

Another important aspect is increasing awareness and stakeholders' participation. This requests to explain to farmers the GAEC concepts and underlining their important role in protecting their land. Moreover, the Member States should assist farmers to identify soil erosion risk areas through modelling and GIS simulations. Moreover, policy makers should also develop the channels for having the farmer's feedback. In the current world with Smartphone developments, each farmer could easily take a photo of soil erosion features or even of applied support practices. Such photos with date and GPS coordinates registered in a database then could potentially be used for several purposes: control of GAEC implementation, validation of soil erosion modelling results, improvement of criteria for incentives, etc.

As the first assessment of support conservation practices at European level, this study has provided constructive feedback on how to improve the LUCAS survey for a more accurate assessment in the future. In the LUCAS 2018 survey a more precise observation of stone walls status (degraded, good condition, newly established), grass margins (poor, good, dense condition) and the presence of contour farming will certainly improve the *P*-factor estimation in Europe.

4.4. Data availability and use

The *P*-factor dataset plus the 3 sub-factors (contouring, stone walls and grass margins) produced in this study will be freely available for download from the European Soil Data Centre (Panagos et al., 2012).

Since those data exist at European scale for the 3 support practices, they cannot be ignored in modelling soil loss at European scale. Based on a large number of field observations, we attempted to model the support practices that reduce soil erosion. The results present the areas in Europe where those practices are implemented. Even if the results are presented at pixel level, it would be better to aggregate these at regional level for demonstrating the concentration and impact of support conservation practices.

5. Conclusions

Support practices have a local effect in reducing soil erosion risk. This is due to the limited application of the support

measures, especially contour farming. The stone walls are also limited at European scale and they can contribute more efficiently if they are built on steep slopes. The application of Good Agricultural Environmental Conditions (GAEC) had an impact in reducing soil loss, especially in hilly areas. In the future, policy instruments such as GAEC could apply to all Member States implementing contour farming in slopes of less than 10% (e.g. 5%), preserving the stone walls and increasing the number of grass margins especially in erosion-sensitive areas.

Despite the shortcomings of the model for *P*-factor prediction at European scale and simplifying assumptions regarding the data, the calculated *P*-factor is a first estimate of the effects of support practices application on soil loss at European level. At catchment or regional level, scientists may have a larger number of field observations for contour farming, stone walls and grass margins. However, those support practices and their local effectiveness (reported in the literature) cannot be ignored in soil erosion modelling neither at regional not at European scale.

The *P*-factor for Europe was estimated to be 0.97 and thus the three support practices discussed reduce the overall soil erosion risk by 3%. Even if the average % reduction is relatively small, the effect is considerably larger in erosion-sensitive regions such as the Mediterranean or the loess belt. Support practices are mainly applied in areas susceptible to soil erosion due to their large values of the *LS*-factor (slope length and gradient) which results in a significant reduction of absolute soil loss. The impact of support practices is mainly observed in agricultural areas where soil erosion risk is reduced by 5%.

Conflict of interest

The authors confirm and sign that there is no conflict of interests with networks, organisations, and data centres referred in the paper.

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